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Cyphastrea salae, a new species of hard coral from Lord Howe Island, Australia (Scleractinia, Merulinidae)

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Abstract

A new zooxanthellate reef-dwelling scleractinian coral species, *Cyphastrea salae* **sp. n.** (Scleractinia, Merulinidae), is described from Lord Howe Island Australia. The new species can be distinguished morphologically from the only other congeneric species on Lord Howe Island, *C. microphthalma,* by the number of primary septa (12 *vs.* 10) and the much taller corallites (mean ± SE: 1.0 ± 0.07 mm v 0.4 ± 0.04 mm). The relationship of *C. salae* to four of the other eleven currently accepted species in the genus was explored through analyses of nuclear (28S rDNA) and mitochondrial (noncoding intergenic region) gene sequences. *Cyphastrea salae* **sp. n.** forms a strongly supported clade that is distinct from a clade containing three species found commonly in Australia, *C. chalcidicum*, *C. serailia*, and *C. microphthalma*. One specimen was also found in the Solitary Islands, another high latitude location in south-eastern Australia. The discovery of a new species in the genus *Cyphastrea* on high latitude reefs in south-eastern Australia suggests that other new species might be found among more diverse genera represented here and that the scleractinian fauna of these isolated locations is more distinct than previously recognised.

Keywords

Biodiversity, biogeography, cnidarian, coral reefs, phylogenetics

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Introduction

The Indo-Pacific scleractinian genus *Cyphastrea* Milne Edwards & Haime, 1848, is one of the most distinctive genera in the recently revised family Merulinidae Verrill, 1865 (Huang et al. 2014). Unlike many other genera in the family Merulinidae, *Cyphastrea* has emerged with the same species composition (Huang et al. 2014), motivating more detailed work at the species level (e.g. Bouwmeester et al. 2015, Arrigoni et al. 2017). The World Register of Marine Species lists 24 nominal species in the genus *Cyphastrea*, of which 11 are considered valid (Hoeksema 2015). The genus was established by Milne Edwards and Haime (1848) for three species, *Cyphastrea microphthalma*, *C. savignyi* and *C. bottae*, distinguished by a compact coenosteum from species in the Indo-Pacific genera *Astrea* Lamark, 1801, *Plesiastrea*, Milne Edwards & Haime, 1848 and the West-Atlantic *Solenastrea* Milne Edwards & Haime, 1848. *Astrea* has been placed within Merulinidae, but is phylogenetically distant from *Cyphastrea* (Huang et al. 2014). *Plesiastrea*, represented by its type species *P. versipora* (Lamarck, 1816), is most closely related to the azooxanthallate corals *Trochocyathus efateensis* Cairns, 1999 and *Cyathelia axillaris* (Ellis & Solander, 1786), all of which are nested within clade XIV (*sensu* Fukami et al. 2008) and not in the Merulinidae (Kitahara et al. 2010, 2016, Huang et al. 2011, Huang and Roy 2013, 2015). Similarly, *Solenastrea* has been placed in clade XIII (*sensu* Fukami et al. 2008) along with several previously unaffiliated coral taxa such as *Oculina* Lamarck, 1816 (Fukami et al. 2008, Kitahara et al. 2010, 2016, Huang 2012). Nevertheless, *Cyphastrea* is the sister group to *Orbicella*, an Atlantic genus, and is therefore distinct among Indo-Pacific corals.

Lord Howe Island is a World Heritage-listed marine protected area in the Tasman Sea with highly distinctive marine fauna including nine endemic fish species (Francis 1993) and 47 endemic species of algae (MPA 2010). Over 100 scleractinian species have been recorded at Lord Howe Island, however, there is very little agreement as to which species are present. Veron and Done (1979) listed 61 species, Harriott et al. (1995) listed 59 species and Noreen (2010) listed 77 species, but only 37 of these species are common to all three studies. Such divergence in the taxonomic composition among different studies suggests that our understanding of this fauna remains incomplete. Lord Howe Island lies over 900 km south of the Great Barrier Reef (GBR) and coral populations are highly isolated (Ayre and Hughes 2004, Noreen et al. 2013). Such isolation creates potential for speciation, however, to date, no endemic scleractinian species have been described from Lord Howe Island. The Solitary Islands are a group of continental islands off the east coast of Australia and are of biogeographical interest due to the co-occurrence of subtropical species and tropical species at the limit of their southern range edges (Veron 1995; Mizerek et al. 2016). Approximately 70 corals species have been recorded in the Solitary Islands (Veron et al. 1974: Harriott et al. 1994).

The aim of this paper is to describe a new species, *Cyphastrea salae* sp n. and also to determine the number of species within the genus on Lord Howe Island. A total of

three *Cyphastrea* spp. has been reported from Lord Howe Island: Veron (1974) listed only *C. serailia*, Veron and Done (1979) added *C. microphthalma*, and Harriott et al. (1995) added *C. chalcidium*.

Materials and methods

Sampling. Specimens of *Cyphastrea* species were sampled using snorkel or SCUBA diving during several trips to Lord Howe Island and the Solitary Islands in eastern Australia (Appendix 2). Digital images of living colonies were taken, and then using a hammer and chisel, a sample of each colony was collected from which an approximate 1 cm^2 subsample was preserved in absolute ethanol for molecular analysis. The rest of each specimen was placed in sodium hypochlorite for up to 48 h to remove all coral tissue, rinsed in fresh water and sun-dried.

The holotype and two paratypes of *Cyphastrea salae* sp. n. have been deposited at the Australian Museum (AM) in Sydney, Australia, along with four voucher specimens of *C. microphthalma* from the same area (Appendix 2).

Imaging and measurements. Images of skeletons were taken with a Canon G12. In addition, a small fragment of clean skeleton was chosen from representative specimens and mounted on a stub using double-sided carbon tape, sputter-coated with a 3nm layer of conductive gold-palladium (AuPd) film and examined using a Jeol JSM5410LVscanning electron microscope at the Advanced Analytical Centre at James Cook University.

To visualise the cross-sectional microstructure of the coralla, corallites were cut from each specimen transversely and then impregnated with epoxy and sectioned to a thickness of ~30 μm following Budd and Stolarski (2009, 2011). The resulting thin sections were examined under stereo or light microscope at magnifications of up to 100x. Images were taken of whole corallites as well as rapid accretion deposits and thickening deposits or fibres within the wall, septa and columella following Stolarski and Roniewicz (2001).

Morphometric measurements. The following variables were measured under a dissecting light microscope with an eyepiece micrometre at 20x magnification on five haphazardly selected corallites from each colony sample; corallite maximum diameter (maximum diameter from outer wall to outer wall), calyx maximum diameter (maximum diameter from the inner wall to inner wall), columella maximum diameter, corallite maximum height above the coenosteum (Appendix 2). In addition, the number of septal cycles and the number of primary septa were also recorded for each of the five replicate corallites per colony (Appendix 2). Finally, five replicate measures of polyp density were made for each colony sample by counting the number of corallites in five haphazardly placed 1-cm^2 quadrats (Appendix 2). Differences in the mean of all continuous variables between the species where compared with *t*-tests with an adjusted alpha of 0.013.

DNA extraction and molecular analyses. Genomic DNA was extracted from each sample using the Qiagen DNeasy kit (Qiagen, Hilden, Germany) following the

manufacturer's instructions. Polymerase chain reaction (PCR) protocols followed Huang et al. (2011) to amplify two molecular markers, the nuclear 28S rDNA (Cuif et al. 2003) and mitochondrial noncoding intergenic region (IGR; between cytochrome oxidase subunit I and the formylmethionine transfer RNA gene) (Fukami et al. 2004). New sequences were deposited in GenBank under accession numbers KY630443-KY630465 (28S) and KY653212-KY653236 (IGR)

Sequences were organised into two separate data matrices using Mesquite 3.03 (Maddison and Maddison 2015), and supplemented with data of *C. chalcidicum*, *C. microphthalma* and *C. serailia* from previously-published analyses (Huang et al. 2011, 2014). A sample from Fiji identified as *C.* cf. *decadia* Moll & Best, 1984, and the outgroups *Paramontastraea salebrosa* (Nemenzo, 1955) and *Echinopora lamellosa* (Esper, 1795) (subclade XVII-I *sensu* Budd and Stolarski 2011; Huang et al. 2014) were also included. Alignments were carried out using the E-INS-i option in MAFFT 7.205 (Katoh et al. 2002, 2009, Katoh and Toh 2008, Katoh and Standley 2013) under default parameters.

Three optimality criteria were used to reconstruct phylogeny separately for each molecular marker. First, the maximum likelihood tree under the GTRGAMMA model was inferred using RAxML 8.0.9 (Stamatakis 2006, Stamatakis et al. 2008) and 50 random starting trees, with 1000 bootstrap replicates. Second, for Bayesian inference, we determined the most suitable model of molecular evolution using jModelTest 2.1.4 (Guindon and Gascuel 2003, Posada 2008, Darriba et al. 2012), testing for 24 models and choosing the best model based on the Akaike Information Criterion (AIC). Bayesian analyses were carried out in MrBayes 3.2.2 (Huelsenbeck and Ronquist 2001, Ronquist and Huelsenbeck 2003, Ronquist et al. 2012). Four Markov chains of 8 million iterations were generated in two runs, logging one tree per 100 generations. MCMC convergence among runs was assessed using Tracer 1.6 (Rambaut et al. 2014), and the first 10001 trees were discarded as burn-in. Third, maximum parsimony trees were inferred using tree searches performed in TNT 1.1 (Goloboff 1999, Nixon 1999, Goloboff et al. 2008) with 10000 random addition sequences, each employing 100 cycles of sectorial searches, ratcheting, drifting and tree fusing. Resampling was carried out through 1000 bootstrap replicates. Gaps were treated as missing data.

Taxonomic account

Cyphastrea, Milne Edwards & Haime, 1848

Genus characters. Corals are colonial by extracalicular budding. The coenosteum is typically spinose and corallites are small (< 4 mm diameter) with low relief (< 3 mm). Septa are in at most three cycles and paliform lobes are usually present. Septal teeth are multiaxial, low (< 0.3 mm) and closely set (< 0.3 mm). Walls are formed primarily by septotheca. Costa and septum centre clusters are weak, there is between 0.3–0.6 mm between costa clusters and < 0.3 mm between septum clusters.

***Cyphastrea salae* sp. n.**
http://zoobank.org/E9B09DB8-0F21-4721-983C-42E5FE9DA607

Material examined. Holotype: Australian Museum AM 81_1530 South Flat, Lord Howe Island (LHI), Australia (-31.5611; 159.0741) 1 m depth. Paratypes: AM 81_1822 Malabar, LHI (-31.5115; 159.0575); AM 81_4749 Malabar West, LHI (-31.5118; 159.0508) and see Appendix 2.

Diagnosis. *Cyphastrea salae* is found on Lord Howe Island and in the Solitary Islands, where it is the only *Cyphastrae* species with 12 primary septa.

Skeletal characteristics of the holotype. The holotype is part of a hillocky colony approximately 50 cm width by 50 cm deep by 50 cm height of a tan colour (Fig. 1A). The most prominent feature of the species in the field are the exsert corallites (Figure 1B). The fragment of the holotype is 10 cm long by 5 cm wide and 4 cm thick (Fig. 1C). Most measured features were uniform: the maximum diameter of the corallites ranged from 2.5 to 2.8 mm, the maximum calyx diameter ranged from 2.0 to 2.4 mm and the maximum diameter of the columella ranged from 0.7 to 0.8 mm. All corallites had two septal cycles and 12 primary septa. In contrast, corallite height was more variable, ranging from 0.4 to 3.3 mm as was the density of corallites which ranged from 5 to 9 cm^{-2}. The holotype has regular free septa and a compact columella (Figure 1D). Septal teeth with multiaxial tips are low (~0.2 mm in height) and narrowly spaced (0.1–0.2 mm), with 7–9 teeth per septum (Figure 1E). Strong pointed or club-shaped granules are scattered on the septal face (Figure 1E). The inter-area on the septa is smooth. Corallite walls are formed by dominant septotheca (Figure 1F). Thickening deposits are fibrous (Figure 1F). Costa and septum centre clusters are weak with approximately 0.3 mm between clusters in the costa and <0.2 mm in the septum. Medial lines are also weak (Figure 1F). Perpendicular crosses absent (Figure 1F). Columella centres are clustered (Figure 1F).

Instraspecific variation. The most common morphology of colonies in the lagoon at Lord Howe Island is hillocky like the holotype, however, some coralla are massive (e.g. 81_1414; Figure 2A, B) or submassive (e.g. 81_3953; Figure 2C, D); and at depth the corolla can be encrusting (e.g. 81_1822; Fig 2E, F and 79_4749; Figure 4G, H). The colour of the colony ranges from tan to green to blue. Corallite diameter ranges from 1.7 to 3.2 mm; calyx diameter ranges from 1.4 to 2.7 mm; columella diameter ranges from 0.6 to 1.0 mm; corallite height ranges from 0.4 to 3.5 mm; number of corallites per cm ranges from 5.0 to 14.0 cm^{-2}; and the number of primary septa ranges from 10 in very small corallites to 17 in the largest (Table 1). Corallite density was noticeably reduced in specimens from greater depths on Lord Howe Island (Appendix 2; Figure 2E, F).

Comparison with *C. micropthalma*. In general, there were few differences in the measured features of the corallites of *C. salae* and *C. microphthalma*. In particular, corallite and calyx diameter were remarkably similar between the two species (Table 1). Corallites were significantly taller ($t = 3.43$, $p = 0.001$) and the columella was larger ($t = 7.12$, $p < 0.001$) in *C. salae* (Table 1). In addition, corallites were significantly more

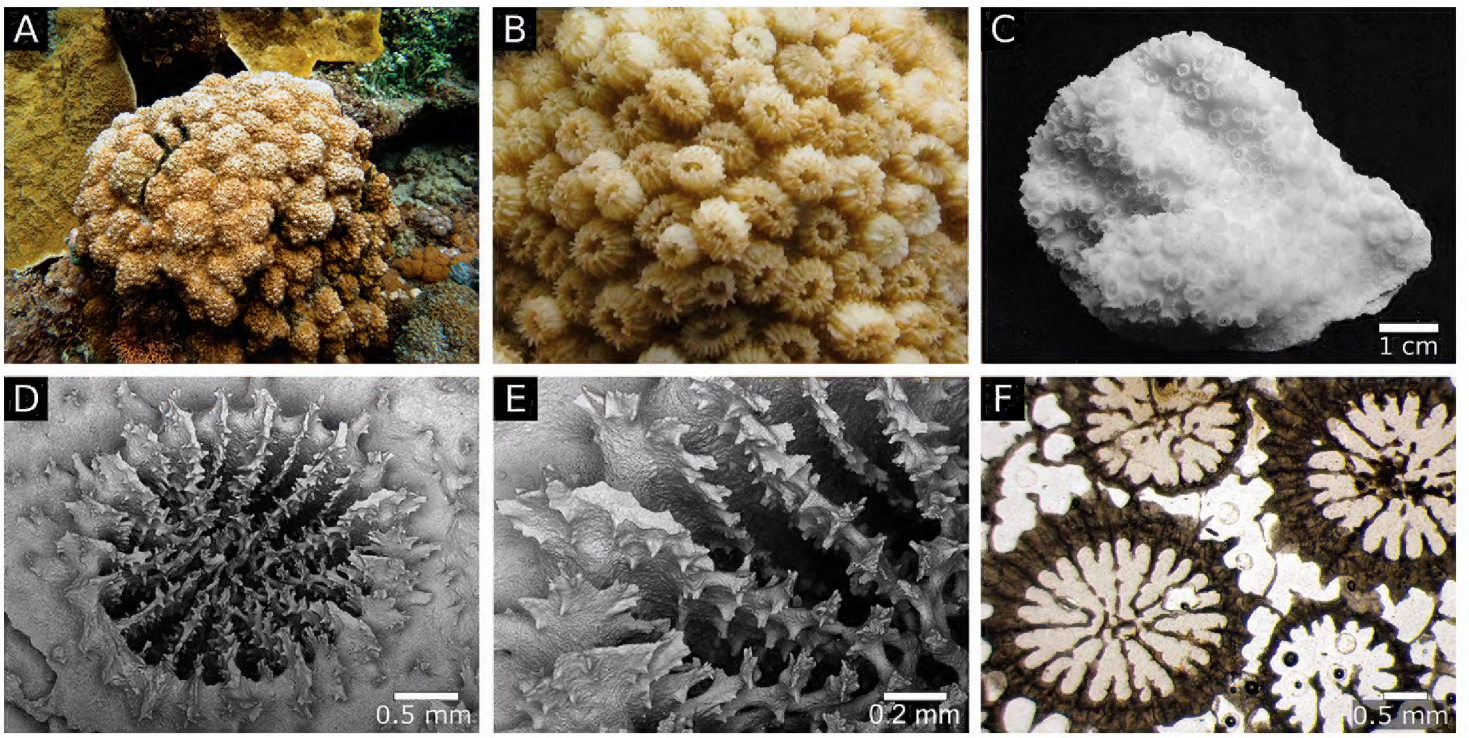

Figure 1. *Cyphastrea salae* sp. n. **A** habit photo of the holotype (G.18222) in situ **B** close up of holotype in situ **C** holotype **D** SEM of corallite **E** SEM of septa **F** transverse thin section.

Table 1. Summary statistics of morphological variables for *Cyphastrea salae* (n = 55) and *C. microphthalma* (n = 40). Measurements in mm.

Variable	Cyphastrea salae			Cyphastrea microphthalma		
	Mean (se)	Maximum	Minimum	Mean (se)	Maximum	Minimum
Corallite diameter	2.3 (0.05)	3.2	1.7	2.2 (0.05)	3.0	1.7
Calyx diameter	1.8 (0.04)	2.7	1.4	1.7 (0.04)	2.5	1.3
Columella diameter	0.6 (0.02)	1.0	0.4	0.5 (0.02)	1.0	0.4
Corallite height	1.0 (0.07)	3.5	0.4	0.4 (0.04)	0.8	0.0
Corallites per cm^2	9.6 (0.30)	14.0	5.0	11.4 (0.35)	16.0	7.0
Number of primary septa	12.0 (0.15)	17	10	10.0 (0.12)	12	7

crowded in *C. microphthalma* which had 11.4 corallites per cm^2 compared with 9.6 per cm^2, on average, for *C. salae* (t = -3.86, $p < 0.001$; Table 1).

The two species are difficult to distinguish in the field based on gross morphology. *Cyphastrea microphthalma* most frequently forms hillocky colonies (Figure 3 A, B), however, it can also occasionally form massive colonies (Figure 3C). Nonetheless, the species can readily be distinguished in the field and the lab on the basis of the number of primary septa which is generally 12 in *C. salae* (Figure 1C, D) *vs.* 10 in *C. microphthalama* (Figure 3D–F). Nonetheless, the modal number of septa in the five corallites counted correctly identified the molecular clade identity in 100% of colonies (Appendix 2).

Phylogenetic analysis. Molecular analyses revealed a monophyletic *Cyphastrea* with two major clades (Figure 4). One clade contained new sequences from all the *C. microphthalma* specimens collected from Lord Howe Island, nested within GenBank sequences of *C. microphthalma* from Singapore and the *C. chalcidicium/serailia* complex. The second clade comprised all of the sequences from *C. salae* from Lord Howe

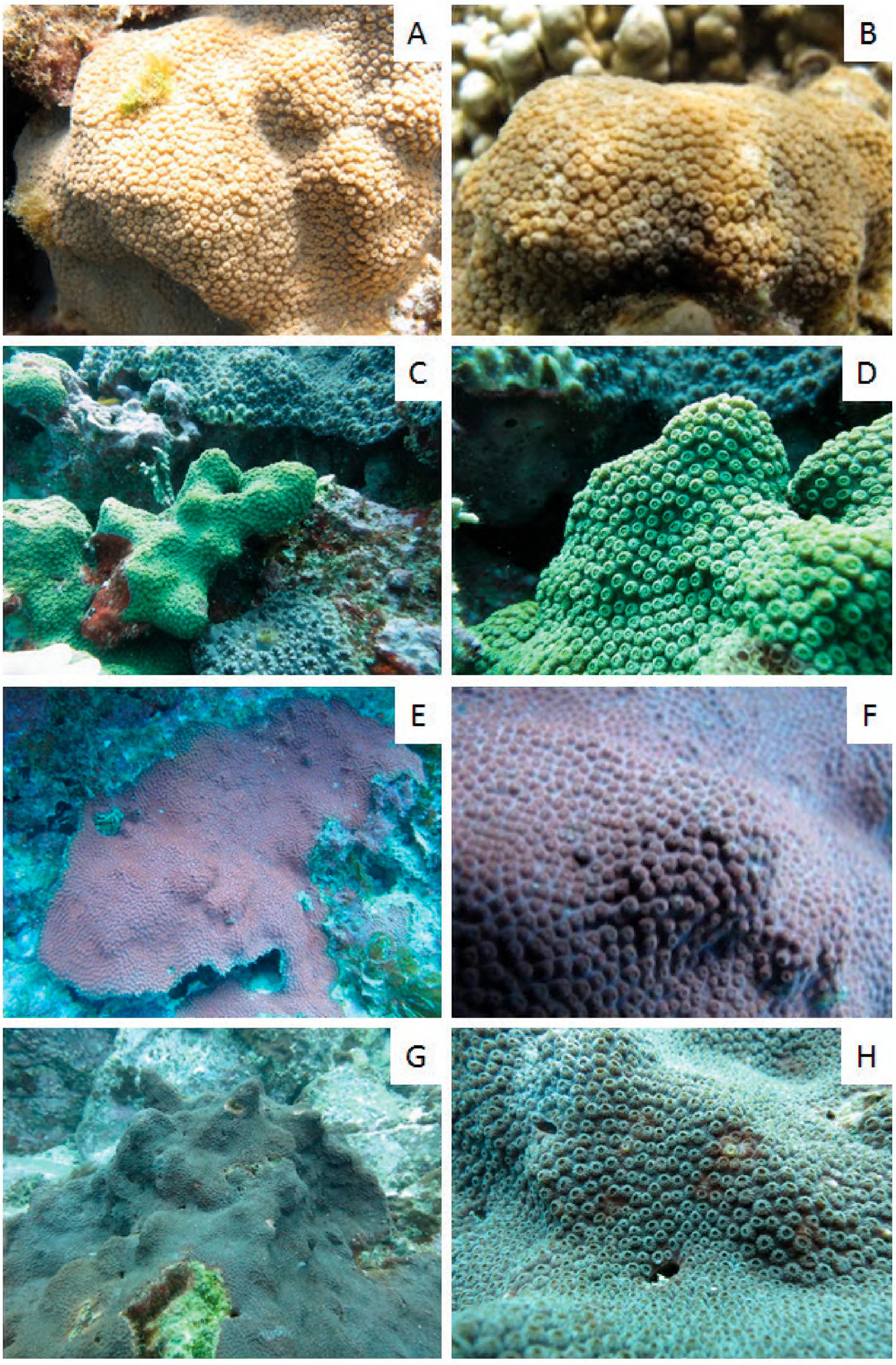

Figure 2. *Cyphastrea salae* in situ. **A, B** AM 81-1414 **C, D** AM 81_3953 **E, F** AM 81_1822 **G, H** AM 79_4749.

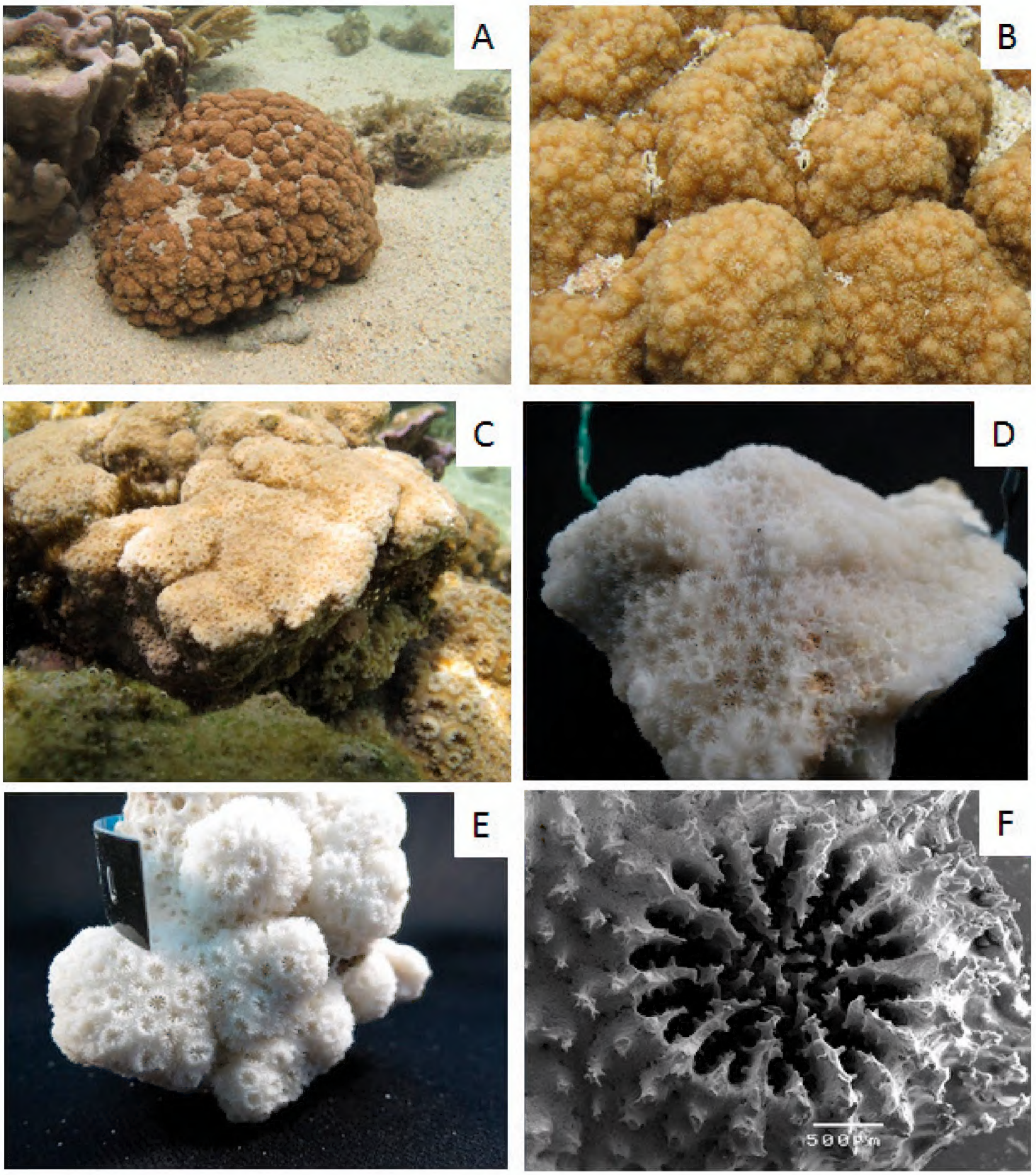

Figure 3. *Cyphastrea microphthalma.* **A, B** AM 81-1612 **C** AM 81_1681 **D** AM 81-1612 **E** AM 81-1660 **F** AM 81-1612.

Island and the Solitary Islands, as well as *C.* cf. *decadia* from Fiji. The first clade was generally unsupported under all optimality criteria for 28S rDNA, but descendent nodes grouping *C. microphthalma* from Lord Howe Island with other *C. chalcidicum/serailia* and *C. microphthalma* sequences had moderate to high supports. The second clade containing *C. salae* was well-supported under all analyses, and is, although the sister relationship to the branching *C.* cf. *decadia* is only strongly supported by IGR (Figure 4).

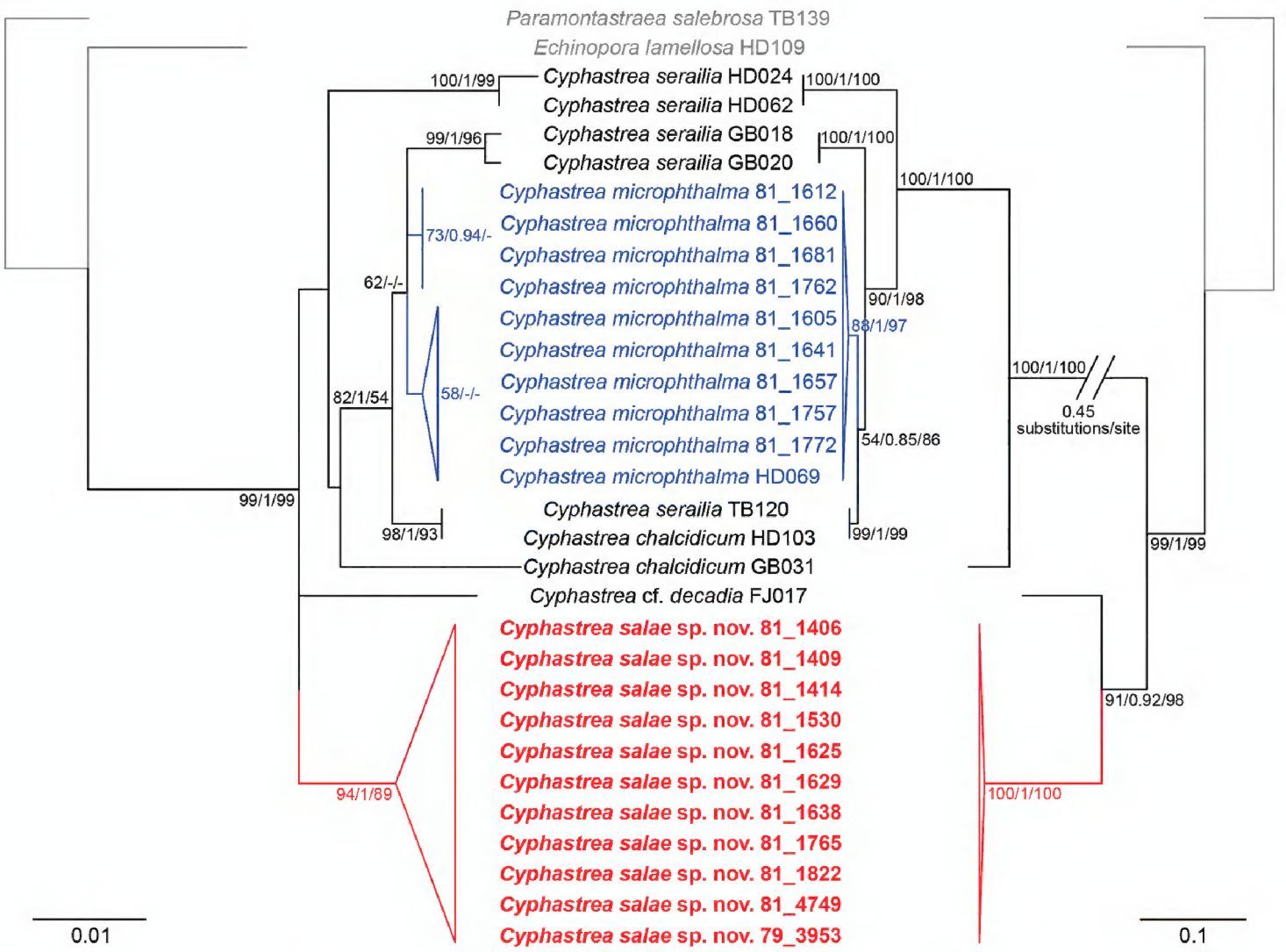

Figure 4. Maximum likelihood phylogenies based on the nuclear 28S rDNA (left) and mitochondrial noncoding intergenic region (right). Taxa in grey are outgroups. *Cyphastrea salae* sp. n. and *C. microphthalma* in red and blue respectively. Numbers adjacent to each branch represent support values (maximum likelihood bootstrap ≥ 50; Bayesian posterior probability ≥ 0.85; maximum parsimony bootstrap ≥ 50).

Cyphastrea salae and *C. microphthalma* originated from two distinct lineages. *Cyphastrea salae* formed a well-supported monophyletic group under all analyses, and is sister group to the branching *C.* cf. *decadia* (Figure 4). All the IGR sequences of *C. microphthalma* clustered strongly as a clade, including the representative from Singapore, but the group is split weakly into two with the 28S rDNA marker. The relationships between *C. microphthalma* and its closely related congeners remained unresolved due to low support by the less variable 28S rDNA (Figure 4).

Etymology. The species is named after Dr Sally Keith and Ms Sallyann Gudge, who have both made significant contributions to understanding and protecting the coral reefs of Lord Howe Island.

Distribution and frequency. *Cyphastrea salae* is common in the lagoon at Lord Howe Island where it commonly co-occurs with *C. microphthalma*. It has been recorded to 18 m depth outside the lagoon. One colony has been positively identified using the molecular markers from Solitary Islands, where it is sympatric with *C. microphthalma*. *Cyphastrea salae* has yet to be recorded in extensive sampling on the Great Barrier Reef and no sequences are present in GenBank.

Discussion

Cyphastrea salae sp. n. is genetically distinct from all other *Cyphastrea* sampled to date, forming a well-supported clade possibly closely related to *C.* cf. *decadia* from Fiji. All 18 specimens of *Cyphastrea* from Lord Howe Island fell into one of two clades suggesting that there are only two species on Lord Howe Island. *Cyphastrea salae* is also morphologically distinct from *C. microphthalma* on Lord Howe Island; in particular, the corallites are taller and the modal number of septa is 12 in *C. salae vs.* 10 in *C. microphthalma* (Table 1).

Amidst the polyphyly of *C. chalcidicum* and the poor support of 28S rDNA for *C. microphthalma*, the strong cohesion of *C. salae* is remarkable. The recovery of the massive *C. salae* as sister group to a branching specimen identified as *C.* cf. *decadia* from Fiji further highlights recent work demonstrating that morphology is a poor indicator of phylogeny (Arrigoni et al. 2016a, 2016b, Terraneo et al. 2016). *Cyphastrea* is a poorly sampled genus, with only six of the 11 currently accepted species sequenced for phylogenetic studies to date. More work is needed in this *C. salae* + *C.* cf. *decadia* clade, which is recovered here for the first time. We expect more comprehensive analyses of this distinct clade to reveal yet more interesting evolutionary patterns.

The number of primary septa is a highly reliable character for distinguishing between these two species on Lord Howe Island. The modal number of primary septa in a random sample of five polyps per colony correctly places all colonies in each molecular clade. Following Veron (2000), *C. salae* keys to *C. serailia* on the basis of its massive growth form, equal costae and 12 primary septa that are not irregularly exsert. *Cyphastrea salae* can be distinguished from *C. serailia* by the fact that corallites are mostly one size *vs.* mixed in *C. serailia*.

The spawning times also indicate a potential reproductive barrier to cross-fertilization between the species on Lord Howe Island. Five colonies of *C. microphthalma* released bundles of sperm and eggs on 19 January 2012 at 21:10 h and one colony of *C. salae* sp. n. released bundles of sperm and eggs on 20 January at 20:30 h (Baird et al. 2015).

The global distribution of *C. salae* remains uncertain. One specimen has been identified in collections from the Solitary Islands (Table 1; Figure 2G, H) and none to date from extensive sampling on the Great Barrier Reef or other sequences listed at GenBank. It is highly likely, therefore, that *C. salae* is a high-latitude endemic. When considered with the recent discovery of another high-latitude endemic, *Pocillopora aliciae* (Schmidt-Roach et al., 2012), this suggests that sub-tropical locations have a much higher level of endemism than previously recognised. This finding greatly increases the recognition of the conservation significance of high-latitude coral reef regions.

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Appendix 1

Table S1. Specimens sampled. All specimens were collected by AHB.

Specimen	Species	Location	Site	Latitude	Longitude	Depth_m	Date	Type	Aust_Mus_accession number
81_1605	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	12/01/2012		
81_1612	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012	voucher	G.18226
81_1641	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1657	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1660	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012	voucher	G.18225
81_1681	*Cyphastrea microphthalma*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1757	*Cyphastrea microphthalma*	Lord Howe Island	Horseshoe Reef	-31.5371	159.0649	1	22/01/2012	voucher	G.18227
81_1762	*Cyphastrea microphthalma*	Lord Howe Island	Horseshoe Reef	-31.5371	159.0649	1	22/01/2012		
81_1772	*Cyphastrea microphthalma*	Lord Howe Island	Horseshoe Reef	-31.5371	159.0649	1	22/01/2012		
81_1530	*Cyphastrea salae*	Lord Howe Island	South Flat	-31.5611	159.0741	1	20/01/2012	holotype	G.18222
81_1625	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1629	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1638	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1765	*Cyphastrea salae*	Lord Howe Island	Horseshoe Reef	-31.5371	159.0649	1	22/01/2012		
81_1822	*Cyphastrea salae*	Lord Howe Island	Malabar	-31.5115	159.0575	8	22/01/2012	paratype	G.18223
81_4749	*Cyphastrea salae*	Lord Howe Island	Malabar West	-31.5118	159.0508	10	20/03/2013	paratype	G.18224
81_1406	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1409	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
81_1414	*Cyphastrea salae*	Lord Howe Island	North Bay	-31.5214	159.0468	1	21/01/2012		
79_3953	*Cyphastrea salae*	South Solitary Island	Buchanen's Wall	-30.2063	153.2657	8	6/03/2013	voucher	G.18221

Appendix 2

Table S2. Trait matrix

colony	species_ molecular	corallite_ number	corallite_ diameter mm	calyx_ diameter mm	columella_ diameter mm	corallite_ height	speta_no_ primary	corallitescm-2	septal_cycles
81_1605	*Cyphastrea microphthalma*	1	2.4	1.7	0.5	0.5	10	11	2
81_1605	*Cyphastrea microphthalma*	2	2.0	1.4	0.5	0.8	10	9	2
81_1605	*Cyphastrea microphthalma*	3	2.0	1.7	0.6	0.1	10	12	2
81_1605	*Cyphastrea microphthalma*	4	2.0	1.7	0.6	0.3	10	10	2
81_1605	*Cyphastrea microphthalma*	5	2.3	1.5	0.5	0.4	10	11	2
81_1612	*Cyphastrea microphthalma*	1	2.2	2.0	0.9	0.5	11	14	2
81_1612	*Cyphastrea microphthalma*	2	2.5	2.0	0.6	0.1	10	12	2
81_1612	*Cyphastrea microphthalma*	3	2.4	2.0	0.6	0.4	10	14	2
81_1612	*Cyphastrea microphthalma*	4	3.0	2.5	1.0	0.7	18	12	3
81_1612	*Cyphastrea microphthalma*	5	2.5	1.9	0.6	0.8	10	11	2
81_1657	*Cyphastrea microphthalma*	1	2.5	1.7	0.6	0.8	10	10	2
81_1657	*Cyphastrea microphthalma*	2	2.2	1.8	0.5	0.4	10	10	2
81_1657	*Cyphastrea microphthalma*	3	2.5	1.7	0.5	0.5	11	8	2
81_1657	*Cyphastrea microphthalma*	4	2.0	1.7	0.5	0.0	10	8	2
81_1657	*Cyphastrea microphthalma*	5	2.2	1.7	0.5	0.3	10	10	2
81_1660	*Cyphastrea microphthalma*	1	2.0	1.5	0.4	0.3	9	10	2
81_1660	*Cyphastrea microphthalma*	2	2.2	1.7	0.4	0.3	10	12	2
81_1660	*Cyphastrea microphthalma*	3	2.2	1.5	0.6	0.4	10	10	2
81_1660	*Cyphastrea microphthalma*	4	2.2	1.8	0.5	0.3	10	7	2
81_1660	*Cyphastrea microphthalma*	5	2.0	1.6	0.5	0.2	7	13	2
81_1681	*Cyphastrea microphthalma*	1	1.7	1.3	0.5	0.0	10	16	2
81_1681	*Cyphastrea microphthalma*	2	1.7	1.3	0.4	0.2	10	15	2
81_1681	*Cyphastrea microphthalma*	3	1.7	1.5	0.5	0.0	9	11	2
81_1681	*Cyphastrea microphthalma*	4	1.7	1.3	0.4	0.2	9	13	2
81_1681	*Cyphastrea microphthalma*	5	2.4	1.5	0.5	0.2	10	12	2
81_1757	*Cyphastrea microphthalma*	1	2.6	1.9	0.5	0.5	12	10	2
81_1757	*Cyphastrea microphthalma*	2	2.5	2.1	0.5	0.0	11	15	2
81_1757	*Cyphastrea microphthalma*	3	2.4	1.9	0.4	0.2	10	16	2
81_1757	*Cyphastrea microphthalma*	4	2.5	2.2	0.6	0.3	10	11	2
81_1757	*Cyphastrea microphthalma*	5	2.2	1.7	0.4	0.5	10	13	2
81_1762	*Cyphastrea microphthalma*	1	2.5	1.8	0.5	0.4	10	8	2
81_1762	*Cyphastrea microphthalma*	2	2.2	1.8	0.4	0.3	10	14	2
81_1762	*Cyphastrea microphthalma*	3	1.7	1.4	0.4	0.2	10	10	2
81_1762	*Cyphastrea microphthalma*	4	2.4	1.8	0.4	0.8	11	10	2
81_1762	*Cyphastrea microphthalma*	5	2.4	1.7	0.5	0.8	10	13	2
81_1772	*Cyphastrea microphthalma*	1	2.3	2.0	0.6	0.3	11	10	2
81_1772	*Cyphastrea microphthalma*	2	2.4	1.7	0.5	0.6	9	10	2
81_1772	*Cyphastrea microphthalma*	3	2.5	1.8	0.6	0.3	10	9	2

colony	species_ molecular	corallite_ number	corallite_ diameter mm	calyx_ diameter mm	columella_ diameter mm	corallite_ height	speta_no_ primary	corallitescm-2	septal_cycles
81_1772	*Cyphastrea microphthalma*	4	2.3	1.8	0.6	0.2	10	13	2
81_1772	*Cyphastrea microphthalma*	5	2.4	1.9	0.6	0.3	10	12	2
79_3953	*Cyphastrea salae*	1	2.2	1.8	0.7	1.2	11	14	2
79_3953	*Cyphastrea salae*	2	2.5	2.0	0.7	1.0	12	10	2
79_3953	*Cyphastrea salae*	3	3.0	2.4	0.8	1.0	15	11	3
79_3953	*Cyphastrea salae*	4	2.2	1.8	0.5	1.3	12	11	2
79_3953	*Cyphastrea salae*	5	2.3	1.7	0.7	0.8	12	14	2
81_1406	*Cyphastrea salae*	1	2.7	2.0	0.7	0.8	13	9	2
81_1406	*Cyphastrea salae*	2	2.8	2.1	0.8	1.2	12	7	2
81_1406	*Cyphastrea salae*	3	2.5	2.2	0.8	1.7	12	10	2
81_1406	*Cyphastrea salae*	4	2.3	1.5	0.6	0.6	11	8	2
81_1406	*Cyphastrea salae*	5	2.2	2.0	0.7	0.8	11	7	2
81_1409	*Cyphastrea salae*	1	3.2	2.7	0.7	0.8	17	10	3
81_1409	*Cyphastrea salae*	2	2.4	1.8	0.5	1.5	11	9	2
81_1409	*Cyphastrea salae*	3	2.8	2.3	0.7	0.5	16	14	3
81_1409	*Cyphastrea salae*	4	2.4	1.4	0.6	1.6	11	8	2
81_1409	*Cyphastrea salae*	5	2.4	1.4	0.6	1.2	11	11	2
81_1414	*Cyphastrea salae*	1	2.4	1.7	0.6	0.5	11	10	2
81_1414	*Cyphastrea salae*	2	2.3	1.7	0.5	0.6	12	13	2
81_1414	*Cyphastrea salae*	3	2.2	1.8	0.7	0.6	12	9	2
81_1414	*Cyphastrea salae*	4	2.2	1.7	0.5	0.8	12	10	2
81_1414	*Cyphastrea salae*	5	2.1	1.5	0.5	0.8	11	12	2
81_1530	*Cyphastrea salae*	1	2.7	2.3	0.8	0.4	12	5	2
81_1530	*Cyphastrea salae*	2	2.7	2.3	0.8	1.5	12	7	2
81_1530	*Cyphastrea salae*	3	2.5	2.0	0.7	1.2	12	9	2
81_1530	*Cyphastrea salae*	4	2.8	2.4	0.7	3.5	12	5	2
81_1530	*Cyphastrea salae*	5	2.8	2.0	0.7	2.0	12	8	2
81_1597	*Cyphastrea salae*	1	3.0	2.3	0.8	0.7	12	9	2
81_1597	*Cyphastrea salae*	2	2.8	2.5	0.8	1.2	12	8	2
81_1597	*Cyphastrea salae*	3	3.2	2.7	0.8	0.6	15	7	2
81_1597	*Cyphastrea salae*	4	2.7	2.2	0.7	0.8	12	10	2
81_1597	*Cyphastrea salae*	5	2.2	1.8	0.6	0.5	11	10	2
81_1601	*Cyphastrea salae*	1	2.4	2.0	0.4	0.4	10	11	2
81_1601	*Cyphastrea salae*	2	2.4	1.7	0.4	1.0	10	8	2
81_1601	*Cyphastrea salae*	3	2.5	2.0	0.6	0.2	10	12	2
81_1601	*Cyphastrea salae*	4	2.5	1.9	0.4	0.2	10	14	2
81_1601	*Cyphastrea salae*	5	2.2	1.8	0.4	0.2	10	10	2
81_1625	*Cyphastrea salae*	1	2.2	1.7	0.5	0.7	12	8	2
81_1625	*Cyphastrea salae*	2	2.2	1.8	0.6	0.7	13	9	2
81_1625	*Cyphastrea salae*	3	2.5	1.9	0.6	1.2	13	11	2
81_1625	*Cyphastrea salae*	4	2.3	1.7	0.5	1.3	12	9	2

colony	species_ molecular	corallite_ number	corallite_ diameter mm	calyx_ diameter mm	columella_ diameter mm	corallite_ height	speta_no_ primary	corallitescm-2	septal_cycles
81_1625	*Cyphastrea salae*	5	2.0	1.7	0.5	0.4	11	10	2
81_1629	*Cyphastrea salae*	1	2.2	1.7	0.5	1.0	12	10	2
81_1629	*Cyphastrea salae*	2	2.0	1.7	1.0	1.4	12	9	2
81_1629	*Cyphastrea salae*	3	2.0	1.7	0.7	1.0	12	10	2
81_1629	*Cyphastrea salae*	4	2.2	1.9	0.6	0.8	12	9	2
81_1629	*Cyphastrea salae*	5	1.8	1.4	0.5	1.0	12	8	2
81_1638	*Cyphastrea salae*	1	2.7	2.0	0.7	1.2	12	8	2
81_1638	*Cyphastrea salae*	2	2.5	2.1	0.6	1.5	12	10	2
81_1638	*Cyphastrea salae*	3	2.6	1.8	0.7	1.2	12	10	2
81_1638	*Cyphastrea salae*	4	2.4	1.9	0.7	0.6	12	12	2
81_1638	*Cyphastrea salae*	5	2.0	1.5	0.6	0.5	10	13	2
81_1765	*Cyphastrea salae*	1	2.1	1.8	0.7	0.8	12	12	2
81_1765	*Cyphastrea salae*	2	2.0	1.5	0.6	1.2	12	14	2
81_1765	*Cyphastrea salae*	3	2.2	1.7	0.7	1.0	12	11	2
81_1765	*Cyphastrea salae*	4	1.8	1.5	0.6	1.2	12	14	2
81_1765	*Cyphastrea salae*	5	1.9	1.5	0.6	0.4	12	11	2
81_1822	*Cyphastrea salae*	1	2.2	1.6	0.4	1.0	12	6	2
81_1822	*Cyphastrea salae*	2	2.0	1.6	0.5	1.2	12	9	2
81_1822	*Cyphastrea salae*	3	2.0	1.6	0.5	0.9	11	7	2
81_1822	*Cyphastrea salae*	4	1.8	1.4	0.4	1.0	11	9	2
81_1822	*Cyphastrea salae*	5	1.8	1.5	0.4	1.2	12	7	2
81_4749	*Cyphastrea salae*	1	2.0	1.8	0.6	0.5	12	9	2
81_4749	*Cyphastrea salae*	2	1.7	1.5	0.5	0.4	12	8	2
81_4749	*Cyphastrea salae*	3	2.2	1.8	0.7	1.5	12	10	2
81_4749	*Cyphastrea salae*	4	1.8	1.5	0.6	1.2	12	7	2
81_4749	*Cyphastrea salae*	5	2.0	1.5	0.6	1.0	12	8	2